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Astrophysics at the frontier: the search for gravitational waves

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ASTROPHYSICS at the FRONTIER: the search for gravitational waves

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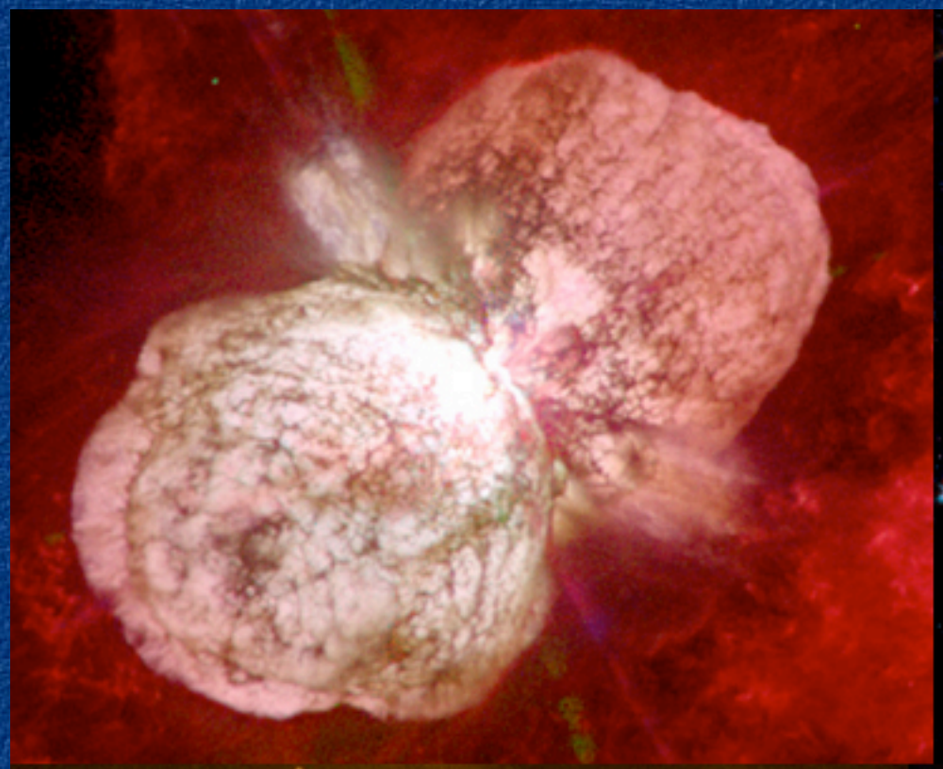
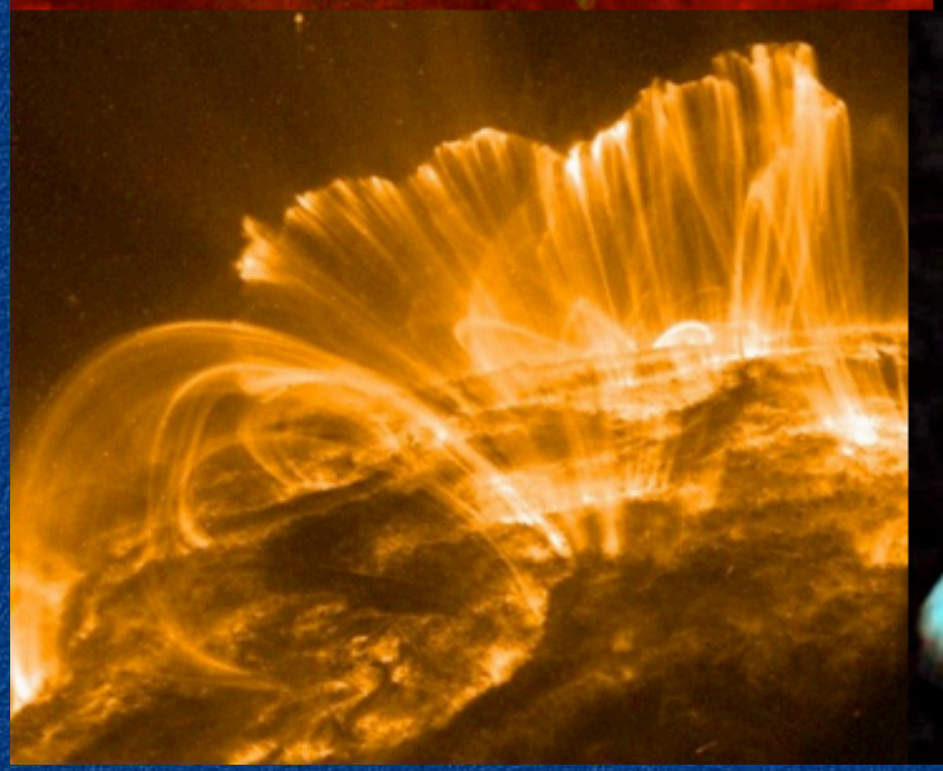
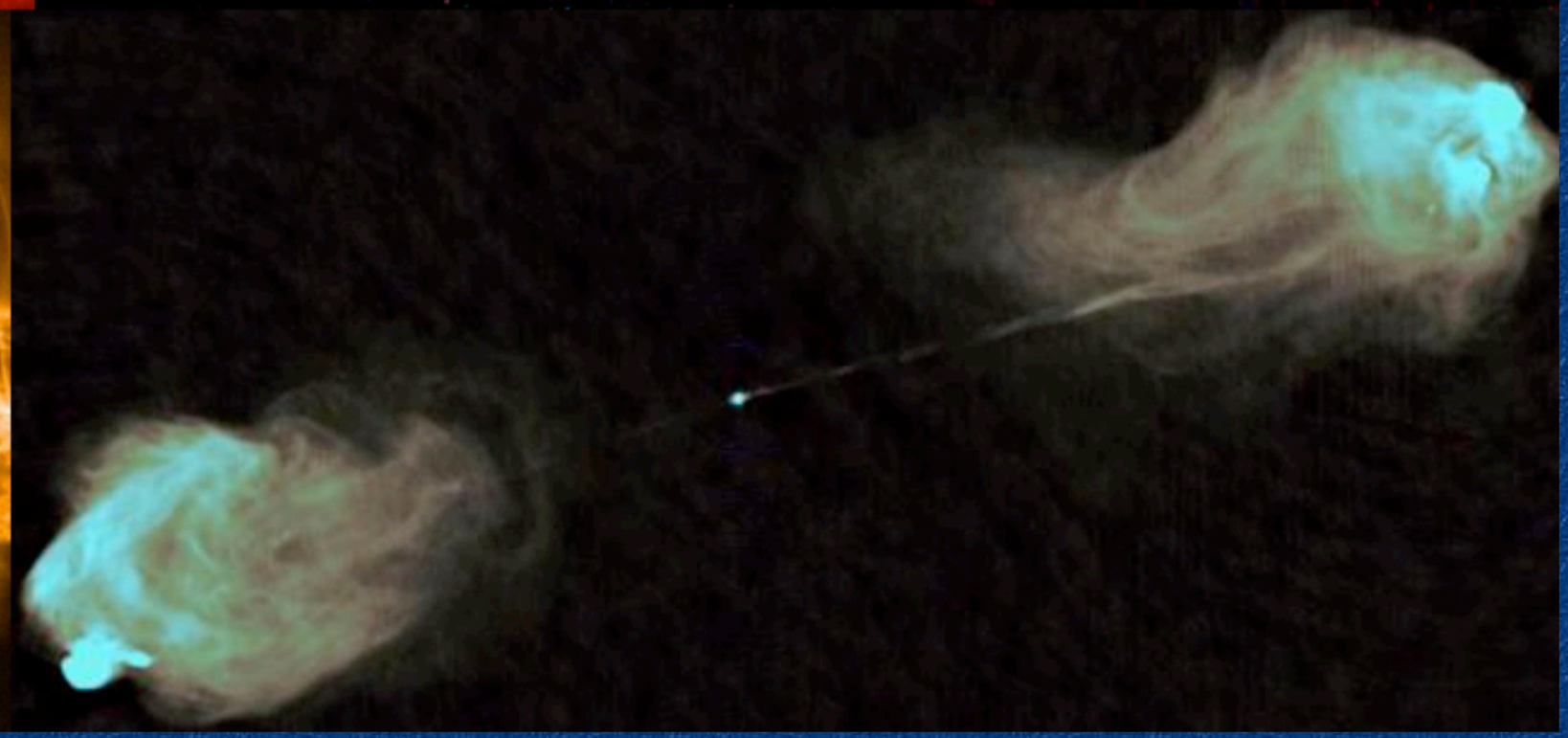
The Cosmos as We Know It...

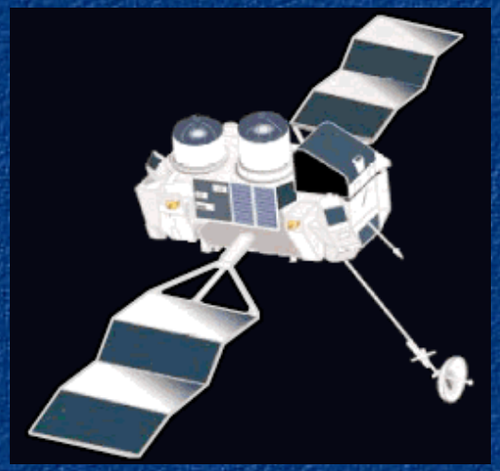


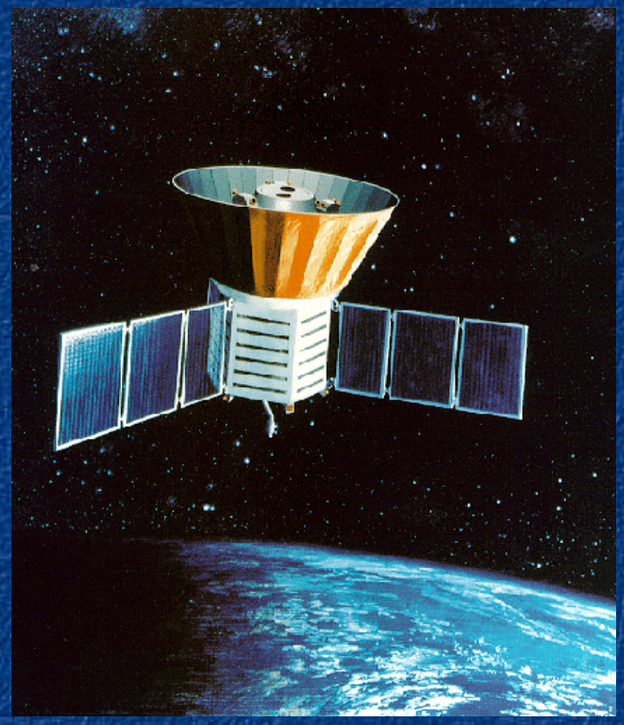


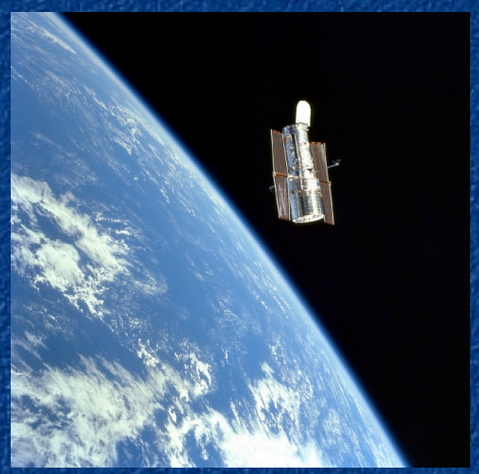


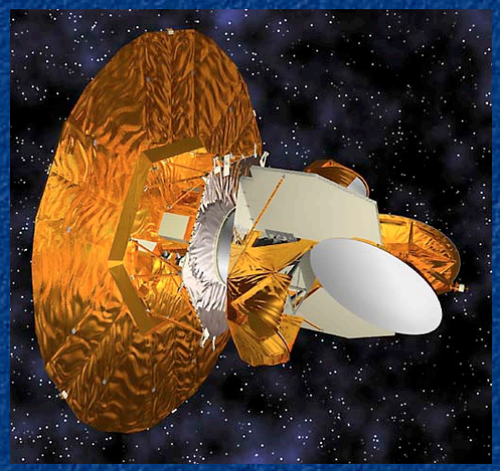
- LIGHT has been our messenger from the Universe.

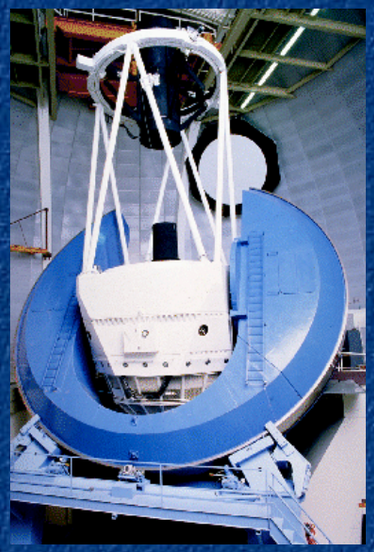
Our Eyes







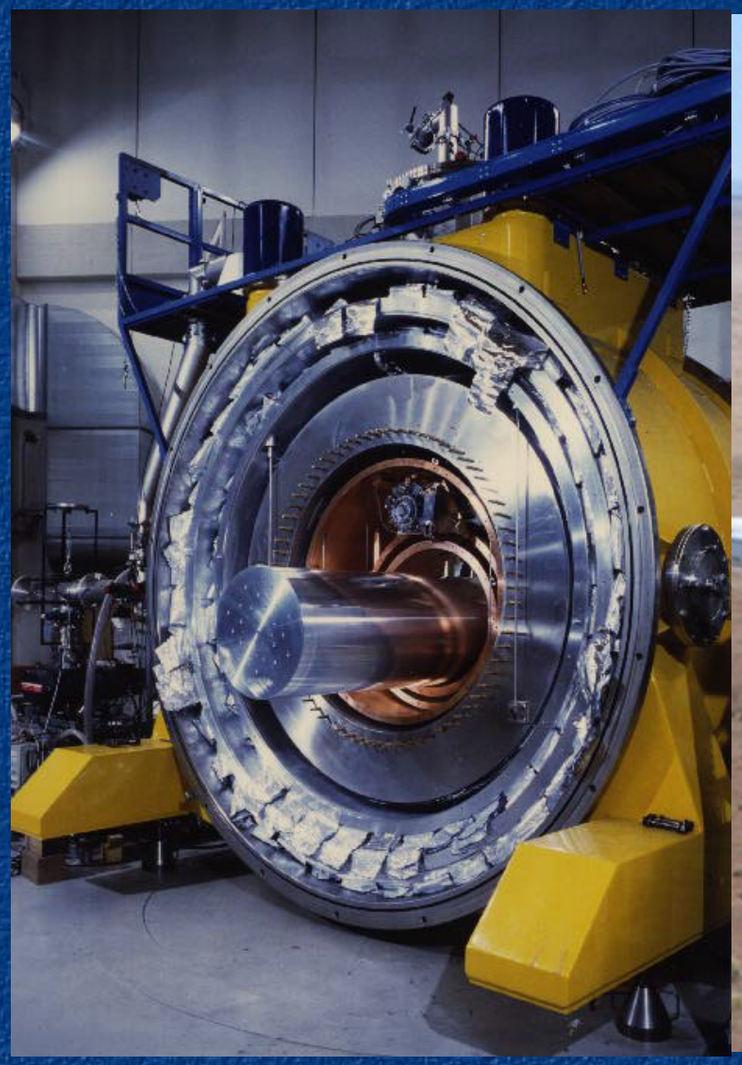




- Light has many forms (visible, infrared, radio, x-ray,....) and we have a myriad of instruments to detect it.

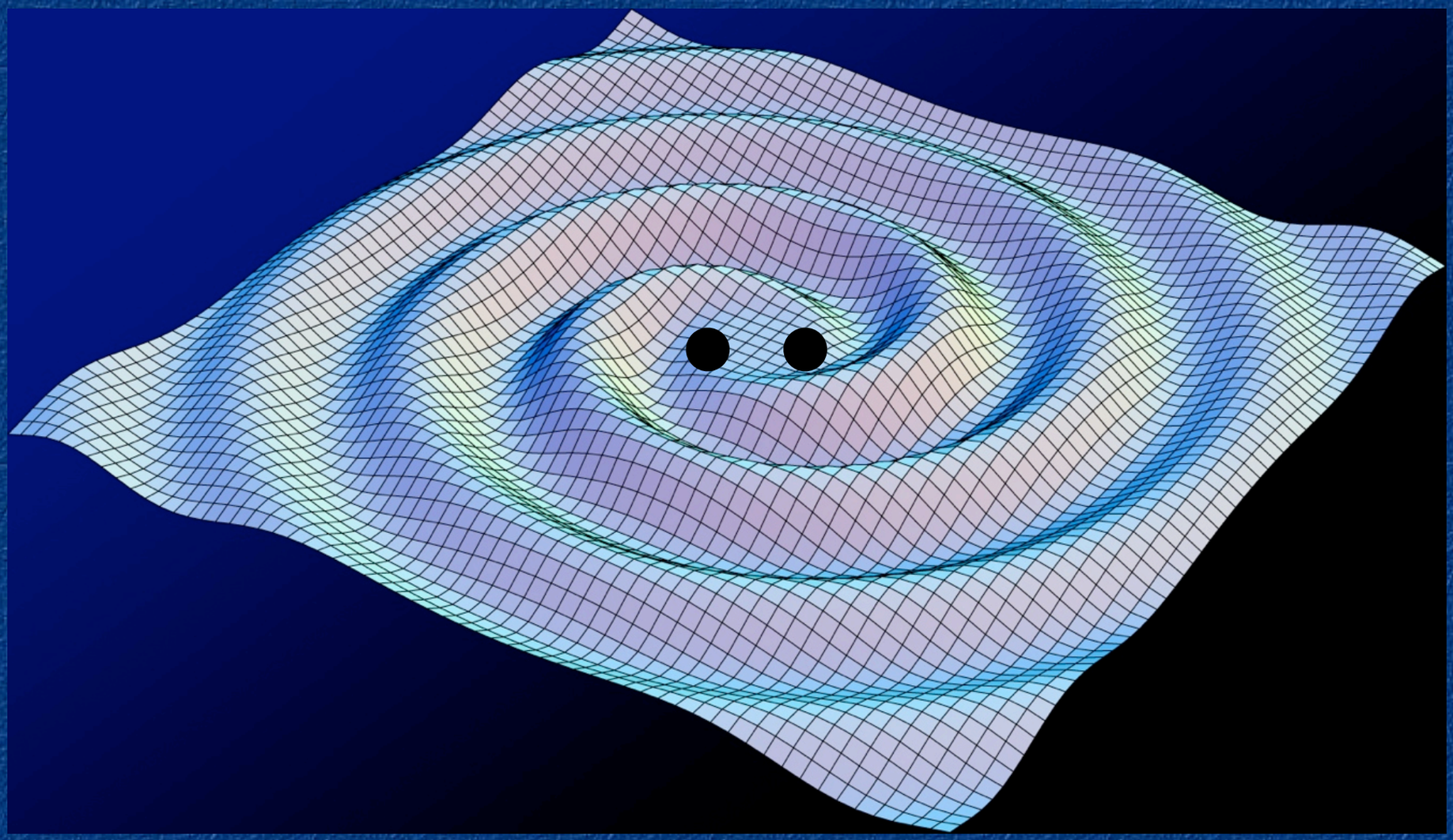
A New Kind of Astronomy

- Here at the start of the 21st Century we are looking at the Cosmos in a fundamentally new way
- Not with light, but with gravity



What are gravitational waves?

- Einstein taught us that space and time were a single entity that forms the underlying fabric of the Cosmos
- Gravitational waves are ripples in the fabric of spacetime which propagate through the Universe



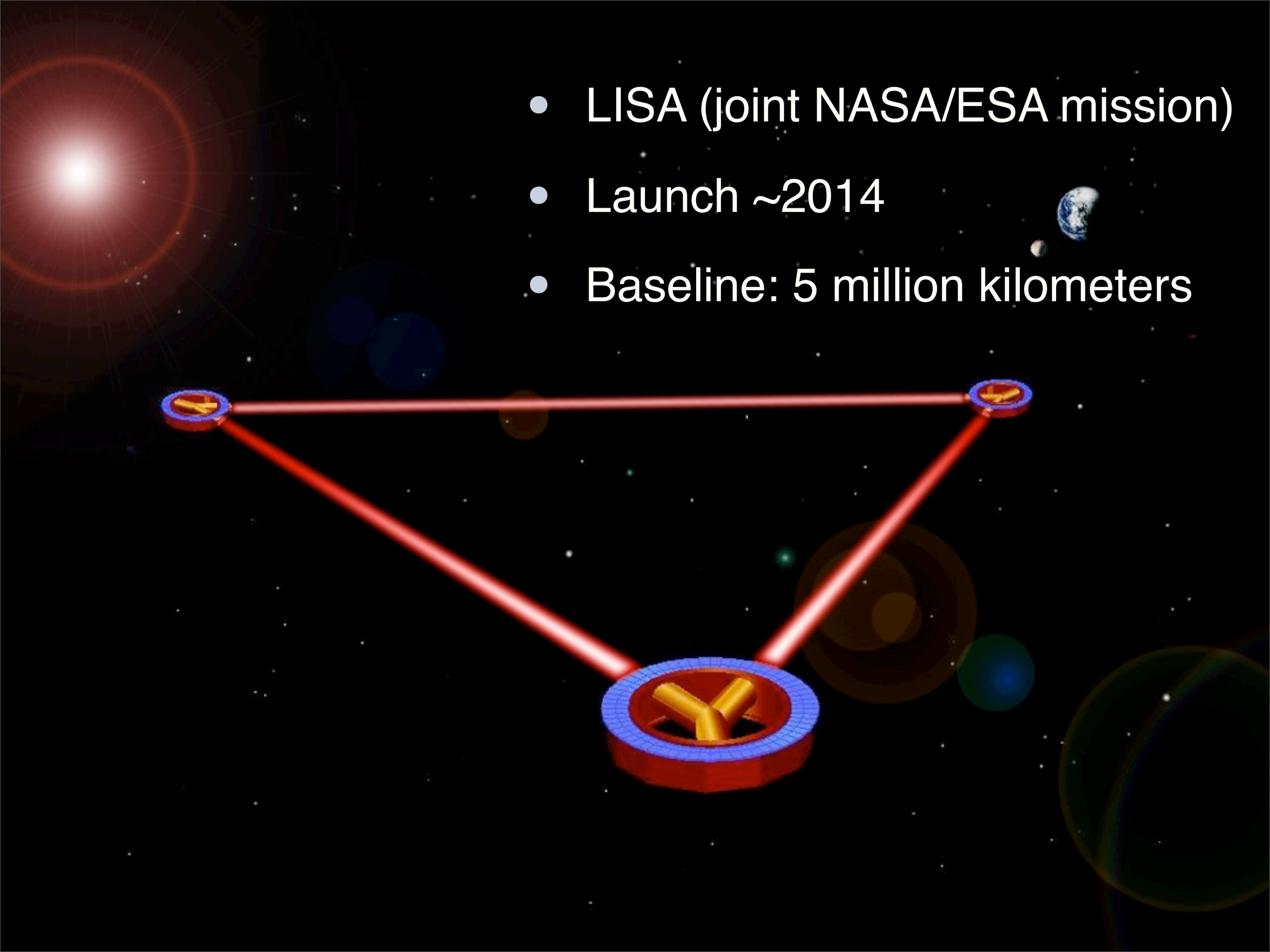
Resonant
Interferometric

LISA

Geo
Auriga
Explorer
Tama
Nautilus
Virgo
LIGO
LIGO
Allegro
Niobe

The World Gravitational Wave Detector Network

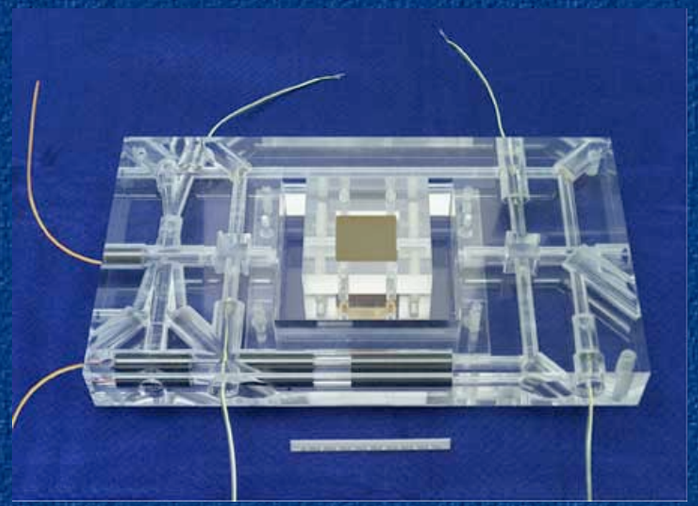
- LISA (joint NASA/ESA mission)
- Launch ~2014
- Baseline: 5 million kilometers



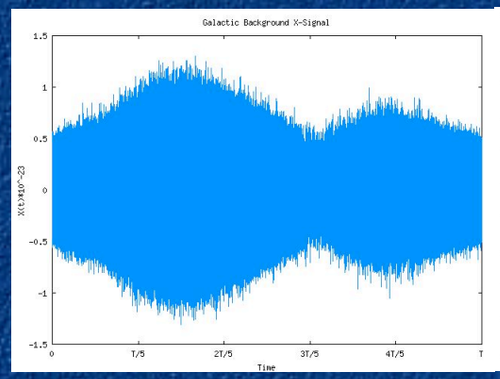
Foundations of GW Astronomy

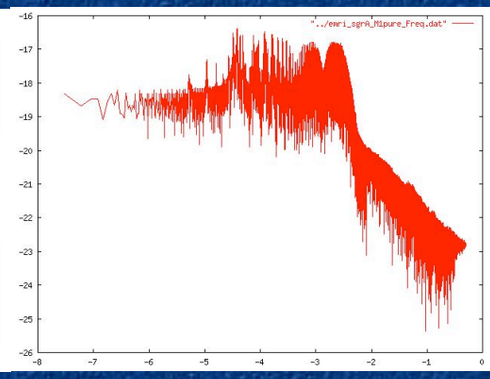
- Gravitational wave astronomy is interdisciplinary, and has three main thrusts:

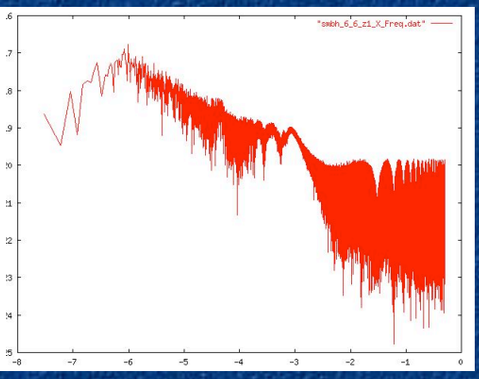
- TECHNOLOGY



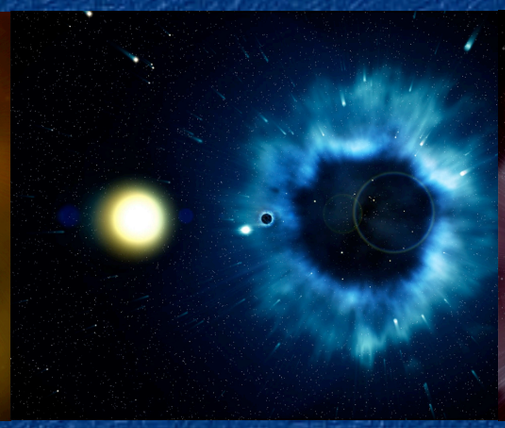
- SCIENCE ANALYSIS (data analysis)







- ASTROPHYSICS & GRAVITATIONAL SCIENCE



Flowdown from GW Astronomy

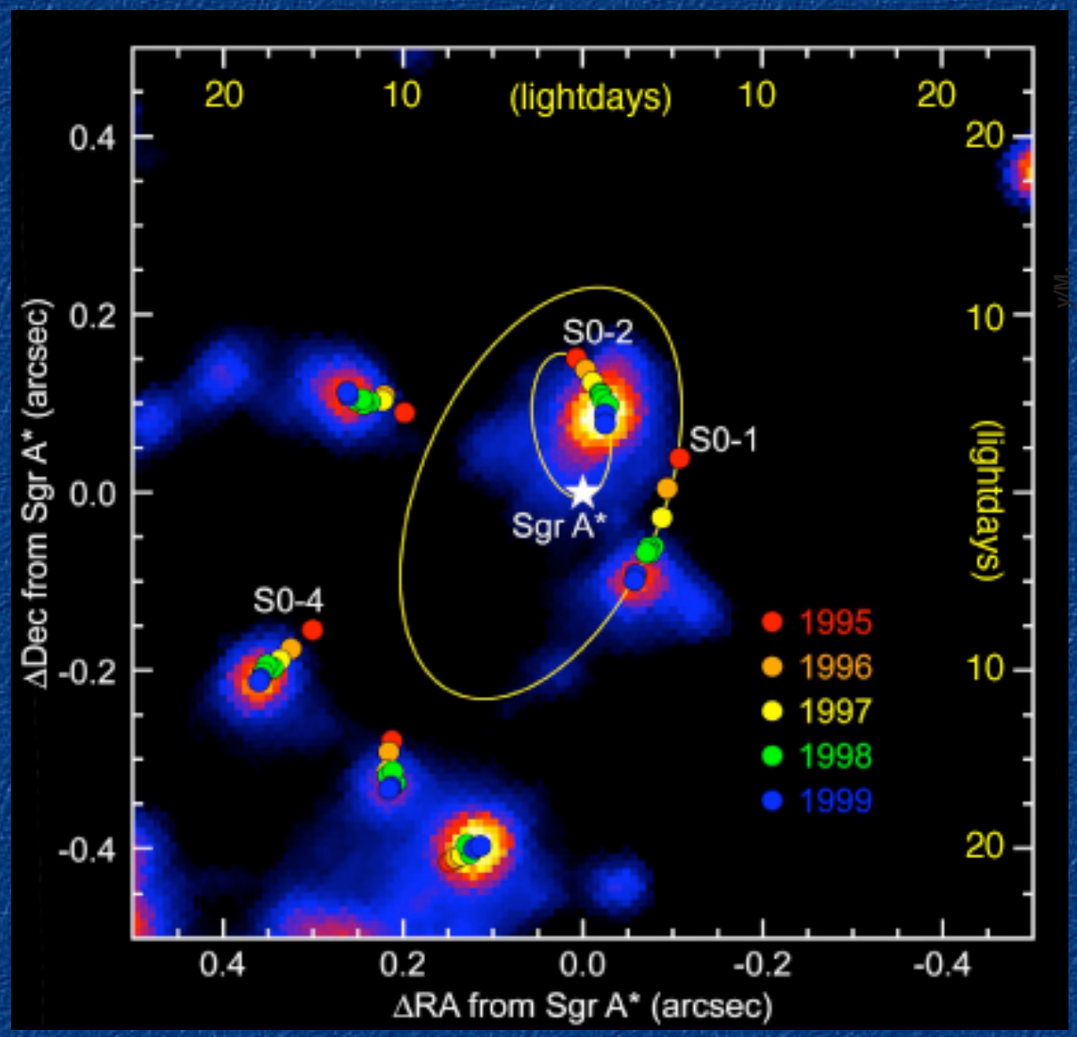
- TECHNOLOGY
  - GW detectors require advanced optics
  - GW detectors require advanced laser systems
  - GW detectors require advanced materials
  - GW detectors require advanced control systems

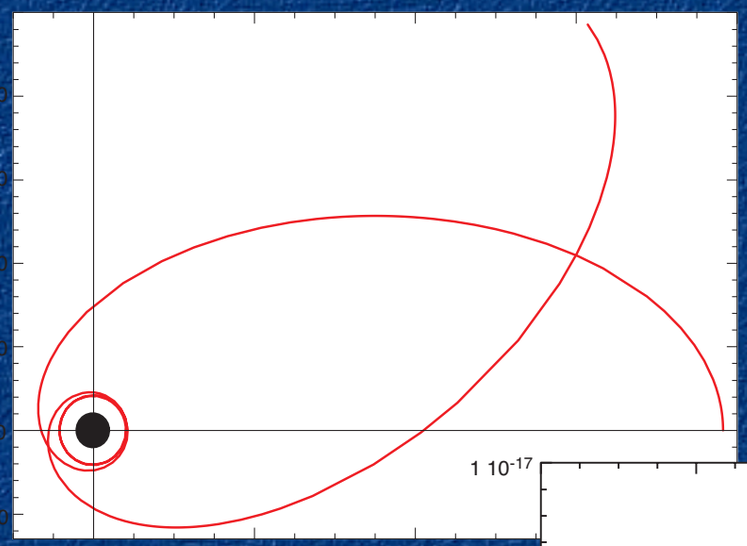
- SCIENCE ANALYSIS (data analysis)
  - GW science requires advanced signal processing
  - GW science requires high performance computing
  - GW science requires environmental monitoring

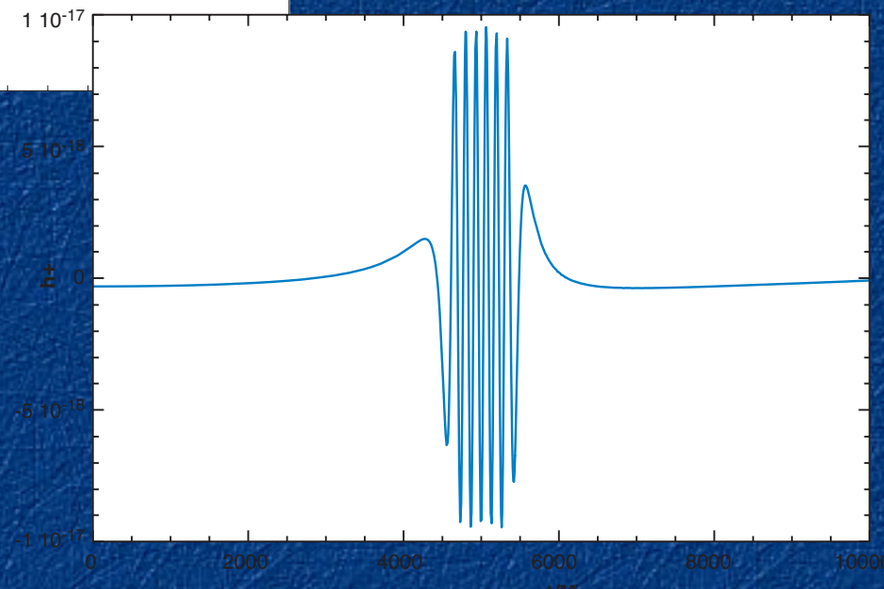
Vignette 1: Small Stars & Black Holes

with Marc Freitag (IoA, Cambridge) & Clovis Hopman (Leiden)

- Compact stellar mass objects sometimes get captured by massive galactic black holes
- The inspiral encodes a map of the black hole spacetime in the gravitational waves



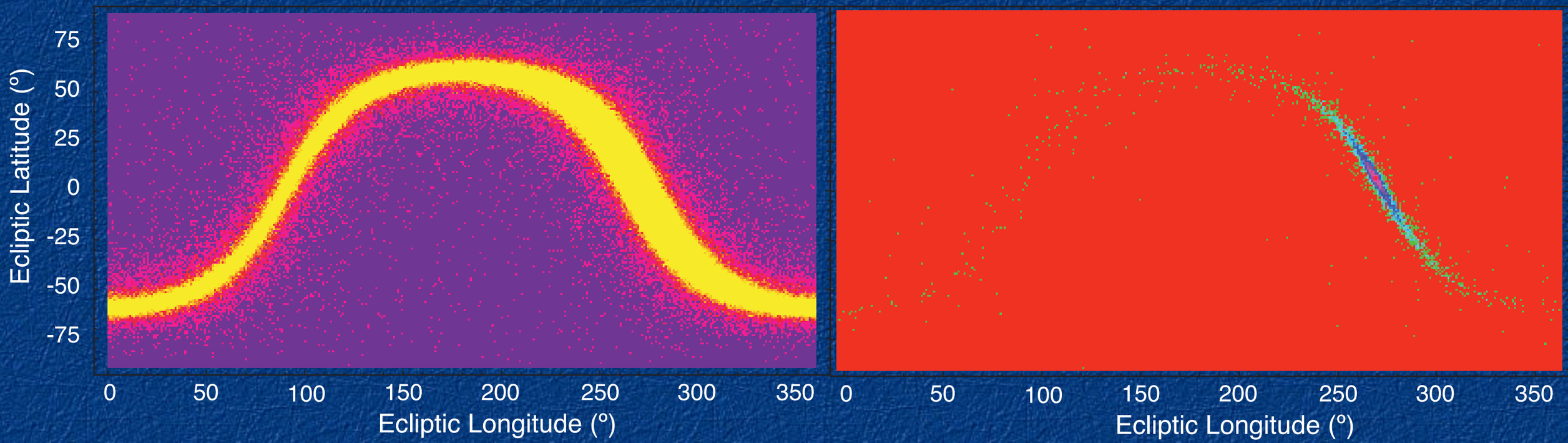




Vignette 2: The Shape of the Galaxy

with Matt Benacquista (UT-Brownsville) & Brett Taylor (Radford)

- LISA will see compact binary stars everywhere in the Milky Way galaxy
- The locations of these stars encodes a map of the shape and history of stellar evolution in the galaxy
- Galactic modeling & science analysis together



My Future at Weber State

- SCIENCE
  - Galactic modeling
  - Multi-messenger astronomy: working with gravitational waves and light together
- G.R.A.I.L. (Gravitational-wave Resource And Information Library)
- GRAVITATIONAL WAVE TEXTBOOK
- MINIONS (student research)
  - I have a box of projects that need done
  - Undergraduates can work in GW astronomy, and publish in mainstream journals [Zaleski & Larson ~2007; Larson, Rubbo, Zaleski & Larson 2006; Rubbo, Larson, Larson & Zaleski 2006; Hiscock, Larson, Routzahn & Kulick 2000; Clark, Hiscock & Larson 1999]

Challenges for GW Astronomy

- COMMUNITY BUILDING
  - GW astronomy is very interdisciplinary
  - Needs to be better communication between gravitational theory, experimental physicists, and astrophysicists.

- BRAIN POWER
  - The GW astronomy effort is extremely understaffed
  - Need to have more professors in the field
  - Need to train more young people in the field
  - Need to retain young people in the field

G.R.A.I.L.

- Proposed to NASA IDEAS
  - Develop materials to use in college classrooms to teach about gravitational wave astronomy
  - Audio Waveform Library
- Collaboration between 19 Institutions (so far)
  - Weber State (Larson – PI)
  - Weber State (Johnston)
  - Mankato (Tom Brown)
  - Franklin & Marshall (Andrea Lommen)
  - Colorado College (Patti Purdue)
  - Youngstown State (Pat Durrell)
  - U Maryland (Cole Miller)
  - Salish-Kootenai College (Tim Olson)
  - UT Brownsville (Matt Benacquista)
  - Penn State (Sam Finn)
  - SUNY-Geneseo (Savi Iyer)
  - Montana State (Bill Hiscock)
  - Pomona College (Tom Moore)
  - Radford University (Rhett Herman)
  - St. Louis University (Greg Comer)
  - Truckee Meadows CC (Dan Loranz)
  - Highline CC (Gregory Reinemer)
  - U Central Florida (Hanno Brueckner)
  - Washington State (Sukanta Bose)
  - East Tennessee State (Ricco Ignace)